Wireless Optical Transmission at 10 Gbps and Beyond

Table of Contents

PART I – CURRENT TECHNOLOGY OVERVIEW

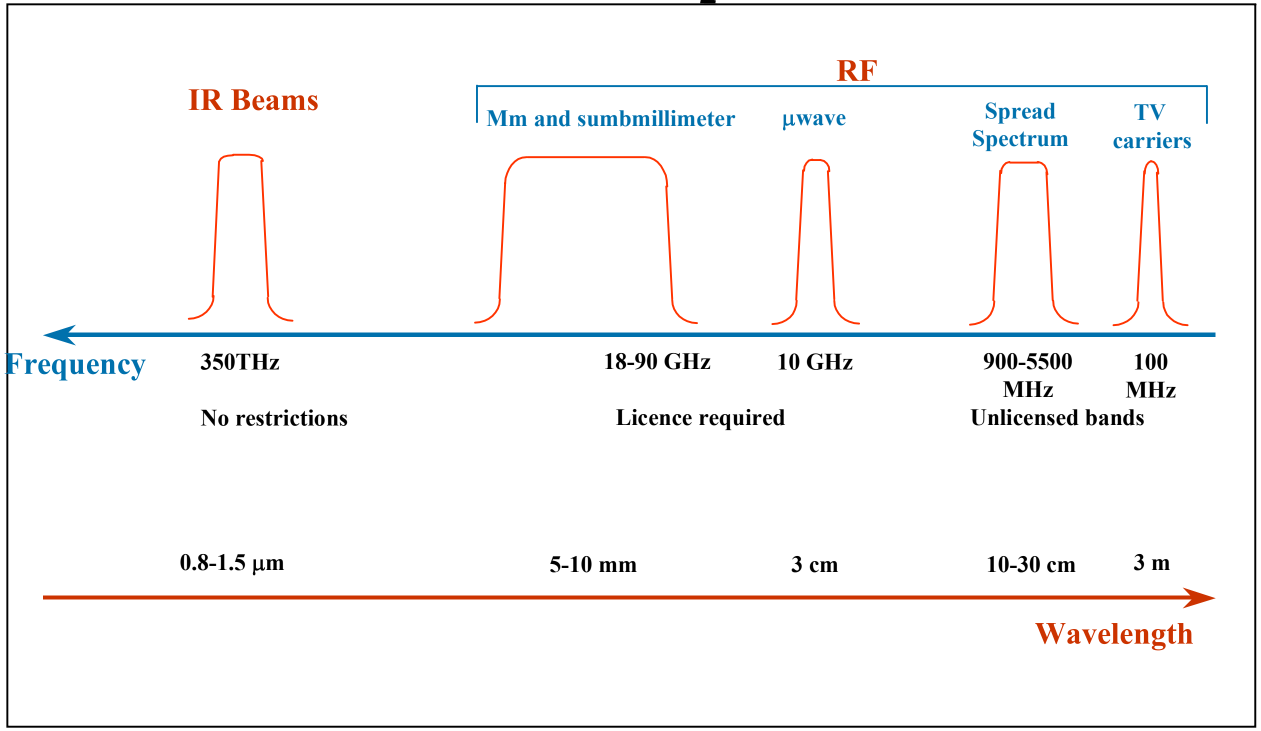
- Bandwidth Blowout (RF vs. IR)
- Trade-offs
- Comparison with Fiber Optics
- The atmosphere
  - Attenuation
  - Scattering
- Equipment Fade Margins

PART II – The PHOTONIC AIR LINK

- Basic concept
- Fiber limitations are dominant
- RF plus IR
- WDM extends bandwidth
- Optical Transformers
- Our wish list for the future

Wireless Spectrum Carrier Frequencies

Wireless Spectrum Carrier Frequencies

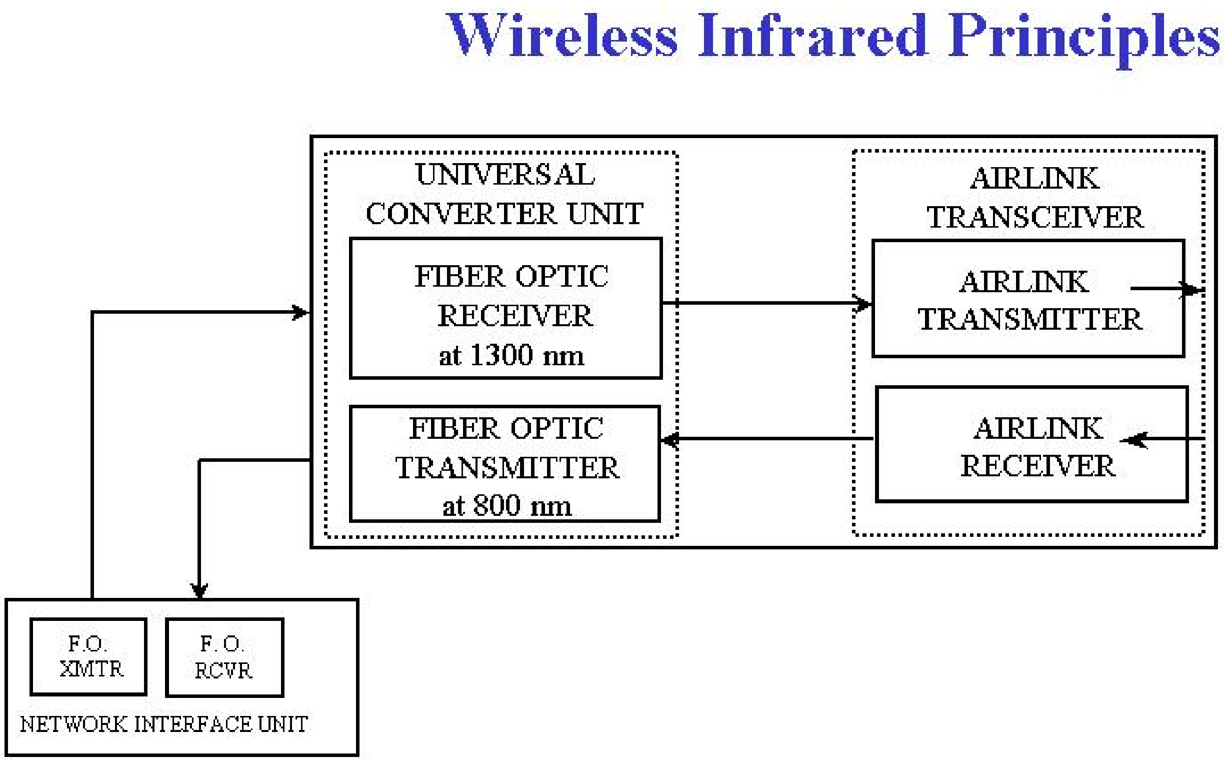


Trade-offs between RF and IR

Trade-offs between RF and IR

Parameter	RF	IR	Implications
Max. Bandwidth	Limited	Unlimited	--
Subject to regulation	Yes	No	Delays
Passes through walls	Yes	No	Security
Dominant noise	Other users	Background	Limits range
Thresholds	-60dBm	-40dBm	LMDS easier with RF
Weather effects	Rain	Fog	Up to -120dB/km
Side lobes	Yes	No	Interference
Health issues	Possibly	No	Eye safety limits

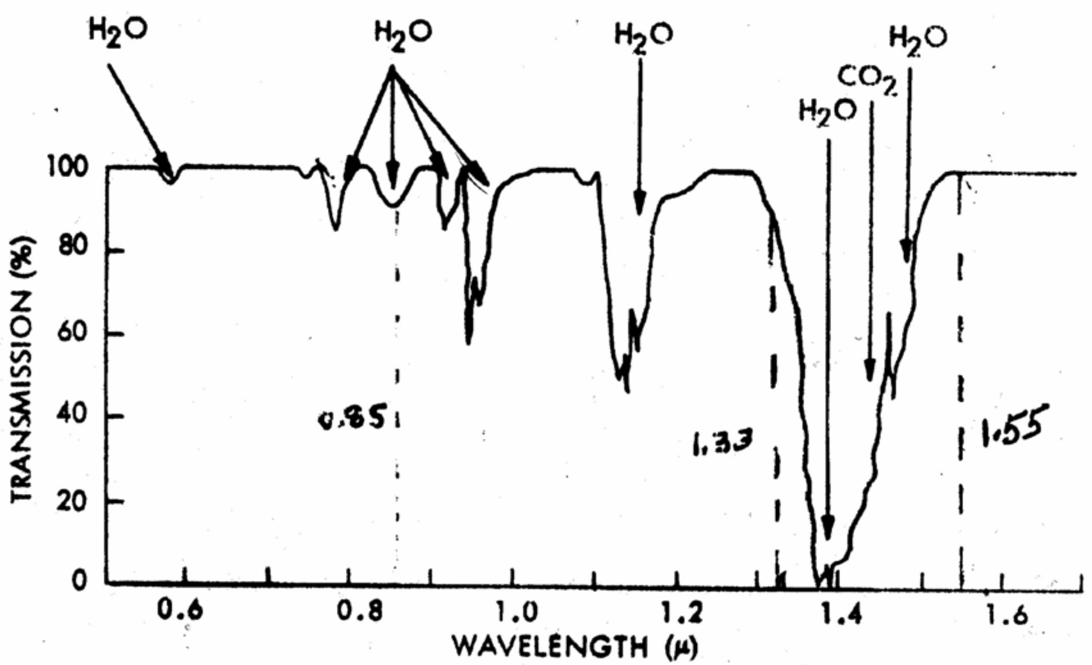
Wireless Infrared Principles



Comparison of Fiber Optics & FSO (Virtual Fiber)

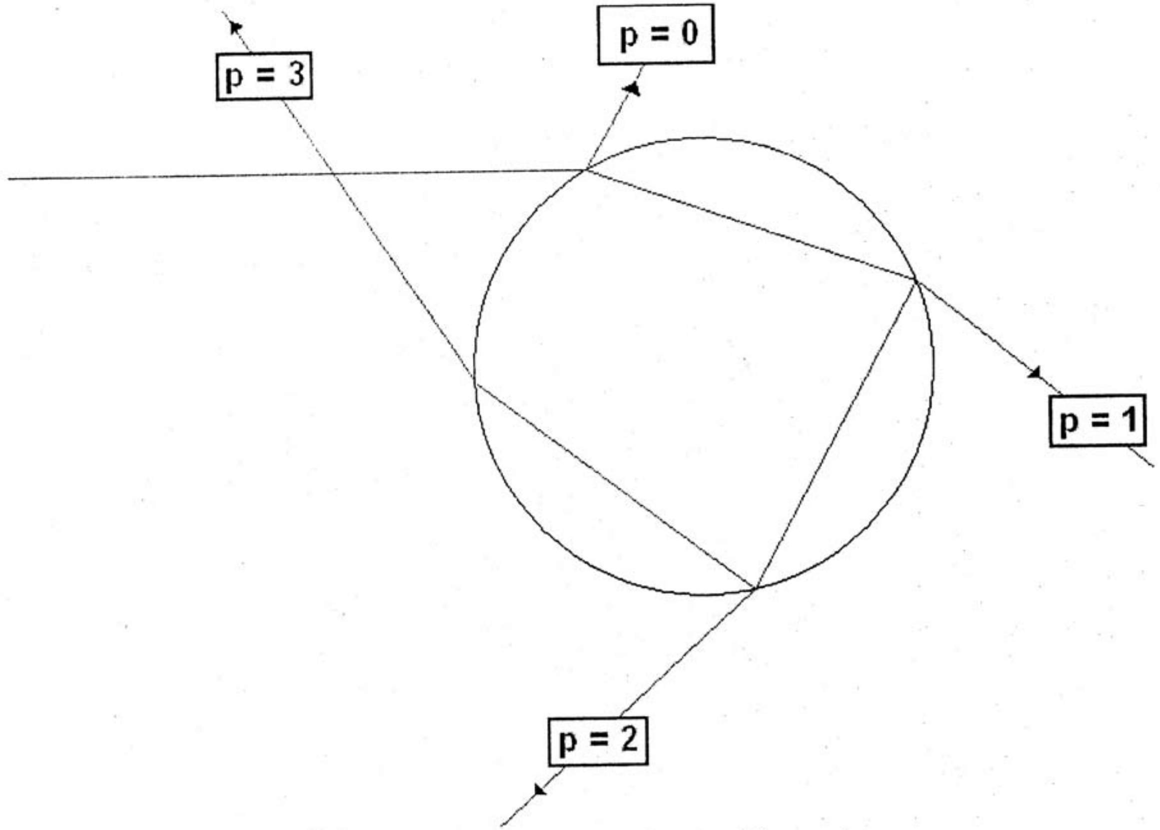
Parameter	Fiber Optic	Virtual Fiber™	Comments
Range/Distance (without repeaters)	> 100 km	2 km (5-10 km clear weather)	LOS over the Last Mile
Loss budget (@ 1Gbps)	> 60dB	<50 dB	Limited by eye safety and background considerations
Environment			
a) Transmission medium attenuation	<0.2 dB/km	>30dB/km (for monsoon, snow)	Fog up to 120 dB/km
b) Background effects	None	Solar background, lights, sky	Optical filtering is a must
c) Weather	None	Big effects	Limit max. distance
d) Birds	None	Possible	Delay 50 msec & reconnect
e) Security	Cladding modes can be detected	No side lobes, very directional beams	FSO more secure than FO
f) Permanent interrupt	Cables can and are being cut	MTBF >10 years	________

Atmospheric Transmission at Sea Level



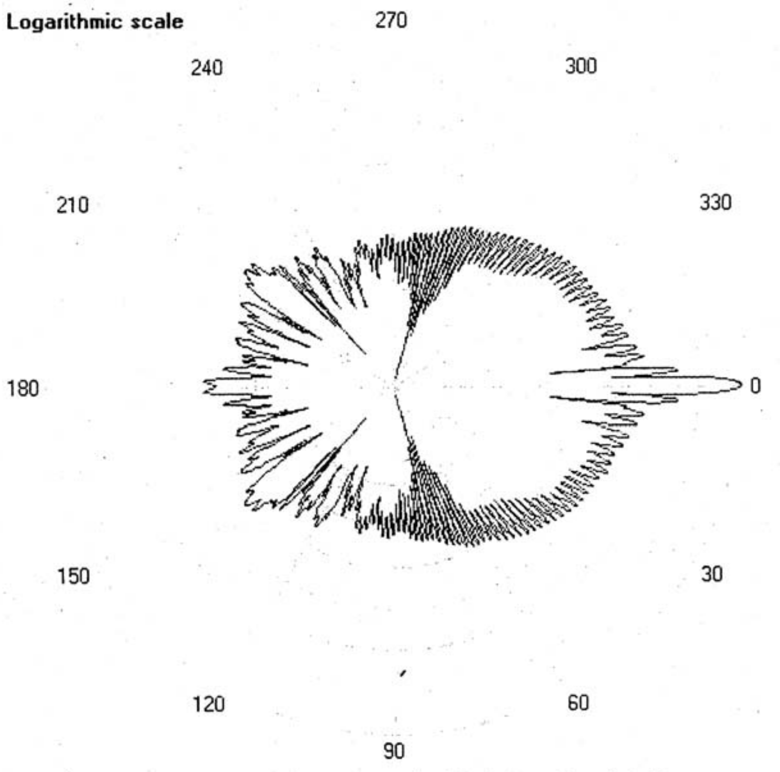
ATMOSPHERIC TRANSMISSION AT SEA LEVEL OVER A 0.3-km PATH

Definition of types of ray path



Definition of types of ray path scattered from a sphere

Polar diagram of scattering of red light



Polar diagram of scattering of red light (wavelength 0.65 μm, perpendicular polarisation) from a water droplet of r = 10 μm

Visibility & Losses

The Visibility (or visual range) is defined as that distance where the radiance of a visible light source is reduced to 1/50 of its initial value:

$$\mathbf{V(in\ km) = ln\ 50/\alpha\ (in\ km^{-1})}$$

In FSO, scattering and absorption losses are represented in dB/km(S) so:

$$\mathbf{S(dB/km) \approx 17/V(km)}$$

Scattering Attenuation of Optical Beams

Weather Condition	Attenuation (dB/km) at 850 nm	Visibility (km)
Clear weather, light haze	0 to 3	50 to 6
Light rain	3 to 6	6 to 3
Heavy rain	6 to 17	3 to 1
Snow	10 to 35	1.5 to 0.5
Light fog	17 to 70	1 to 0.25
Heavy fog	80 to 200	0.2 to 0.08
Clouds	300 to 500	0.06 to 0.03

Neither snow nor sleet…

UWIN802 installed in Riga, Latvia by “Erseta” in September, 1996.

Ethernet 10 Mbps, ~200 m

“….it works quite well and we have no problems”.

Fade Margin Calculation

Fade Margin calculation

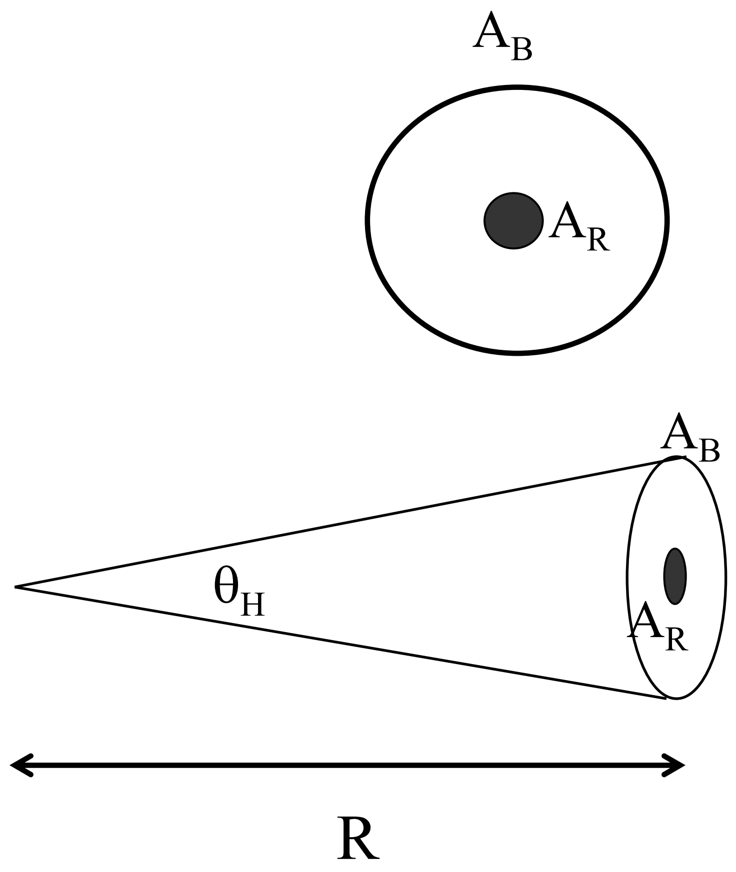
- Loss Factor = L.F. = 10 log A_B/A_R [dB]

    - A_B = Beam area; A_R = Receiver area
    - $A_B \sim R^2\theta_H\theta_V$ where
    - θ_H = azimuth angle
    - θ_V = elevation angle, R = distance

- Loss Budget = L.B. = 10 log P_B/P_t [dB]

    - P_B = Power in the beam
    - P_t = Threshold power

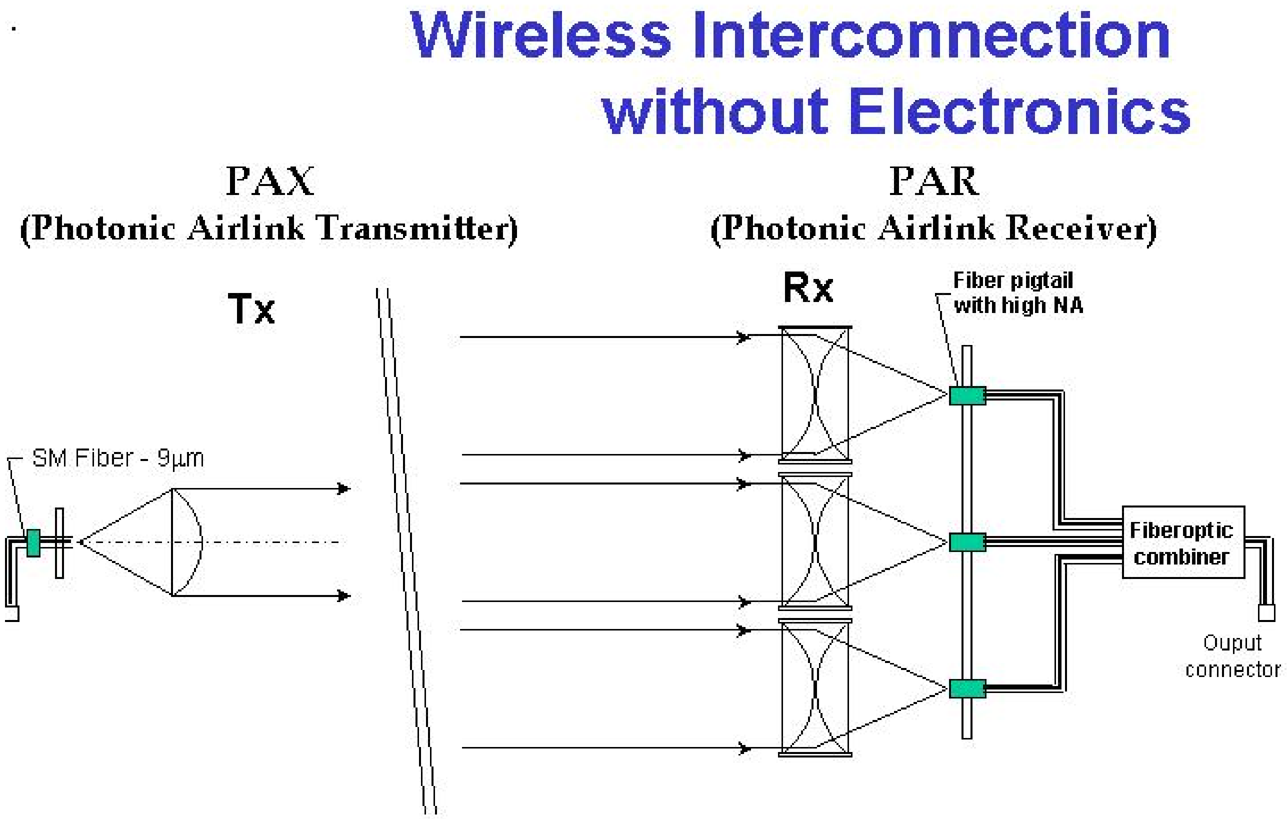
- Fade Margin = F.M. = L.F. - L.B. [dB]



Today, the Photonic Air Link has a special niche in a niche technology

Tomorrow, it may become the key commodity in a mainstream market

Wireless Interconnection without Electronics

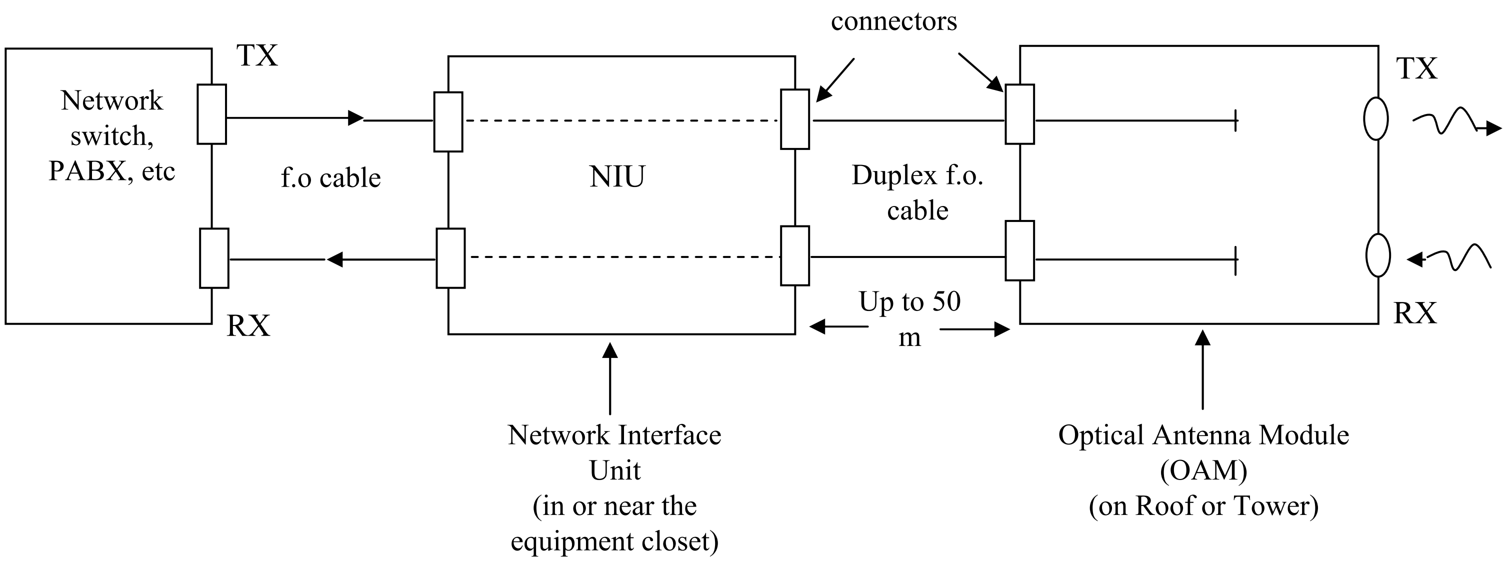


Current MMF Fibers Used in FSO

Fiber type	*Core diam. (microns)*	*NA*	*Bandwidth MHz.km*	*Max length at Gigabit ETH (meters)*
Graded Index	62.5	0.28	400	200
Graded Index	100	0.29	100	50
Semi GI	125	0.30	100	50
Semi GI	200	0.37	100	50
Step Index	400	0.39	10	10
Step Index	600	0.39	8	5

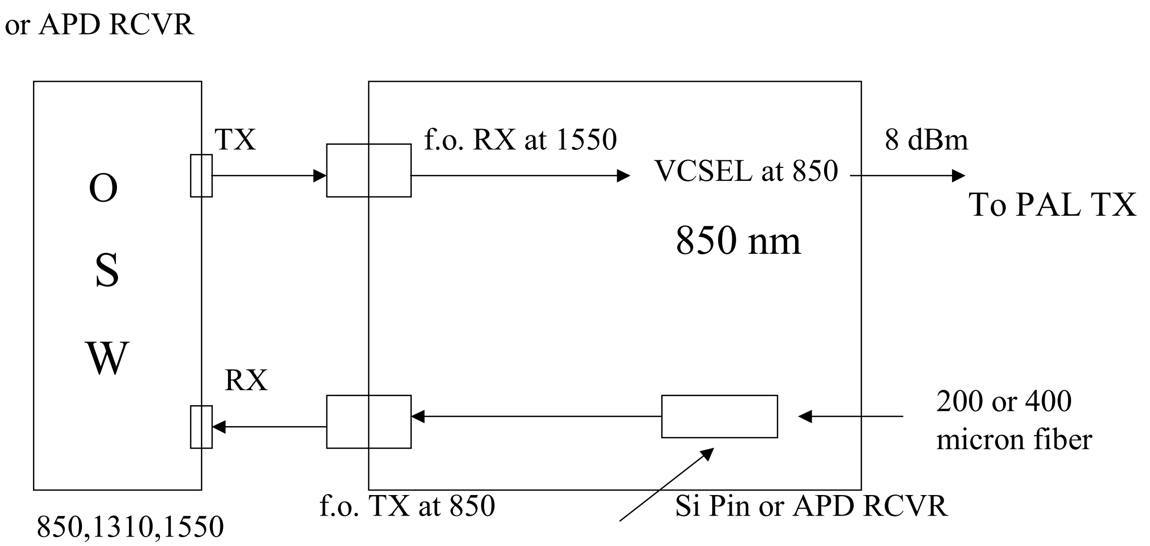
Note: Gradium lens 50 mm diam. has focal length 80 mm (NA ≈ 0.3)

Key Components of High Bandwidth Transmission System



Media Converter Designs

All λ MC



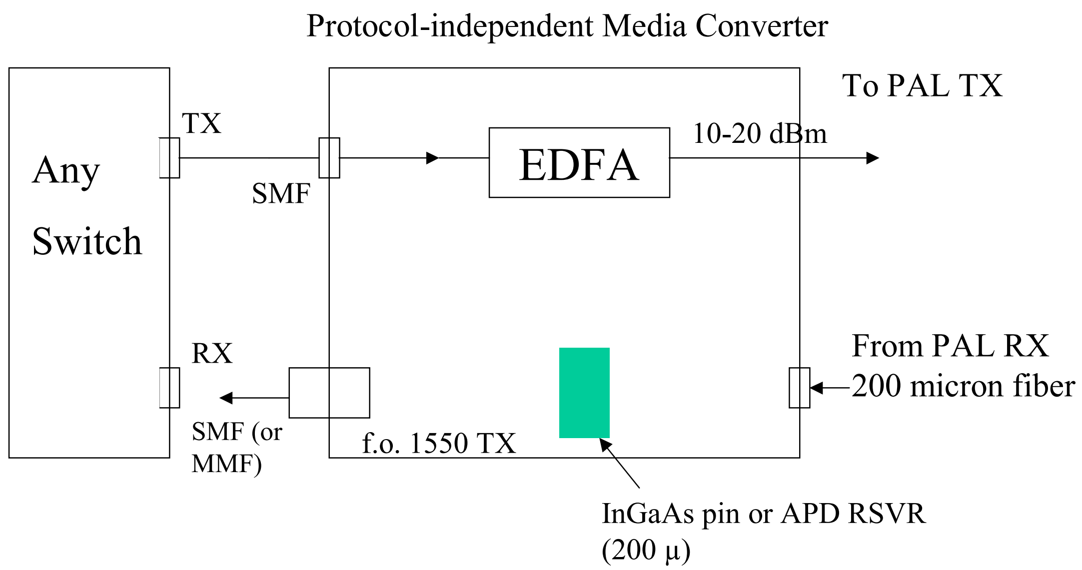
Protocol – independent

Wavelength – independent

Frequency independent

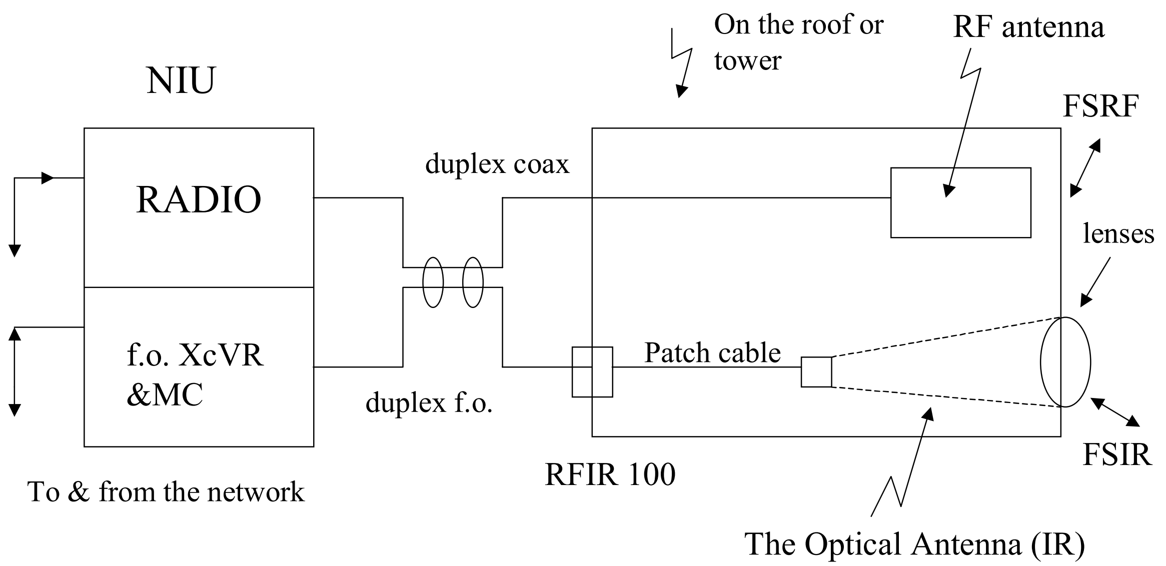
Media Converter Designs

Media Converter Designs
(For 1550 nm switches only)



RFIR 100 System

RFIR 100 System



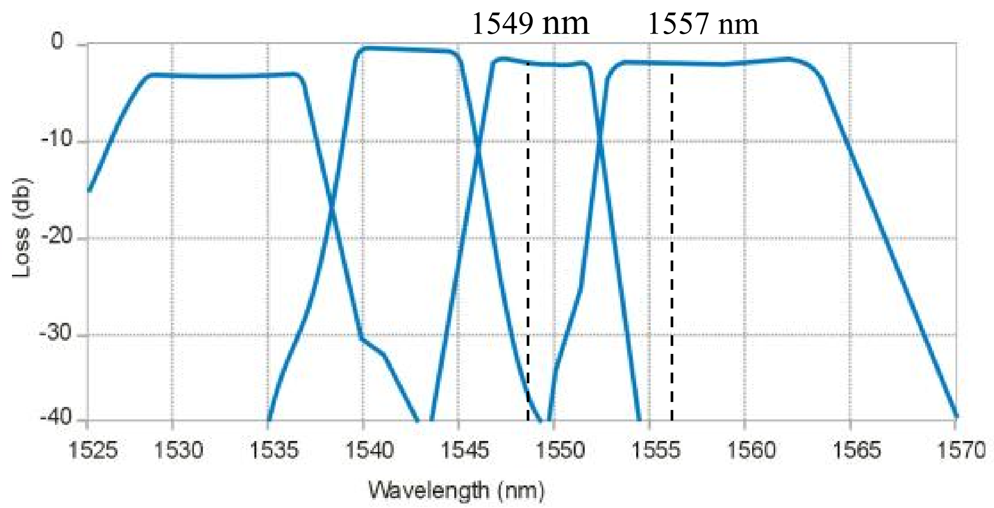
 Connectivity Unlimited ™ MRV

MUX/DeMUX with MMF

MUX / DeMUX With MMF

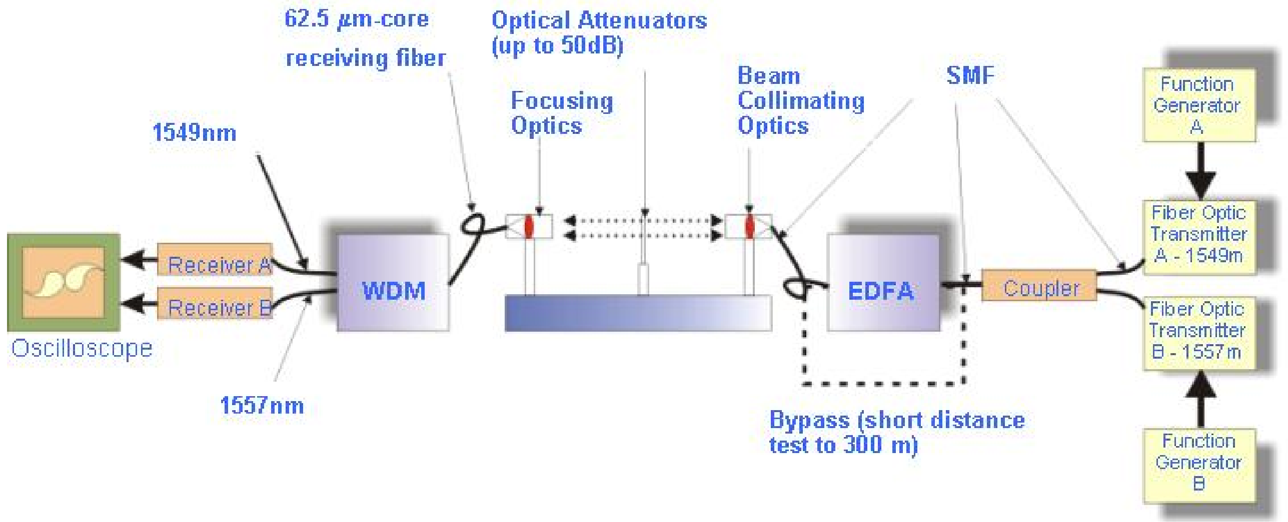
Fiber: Corning Multi Mode 62.5/125 um in 3mm cable, with FC/APC connectors

Testing Temperature: 23°C

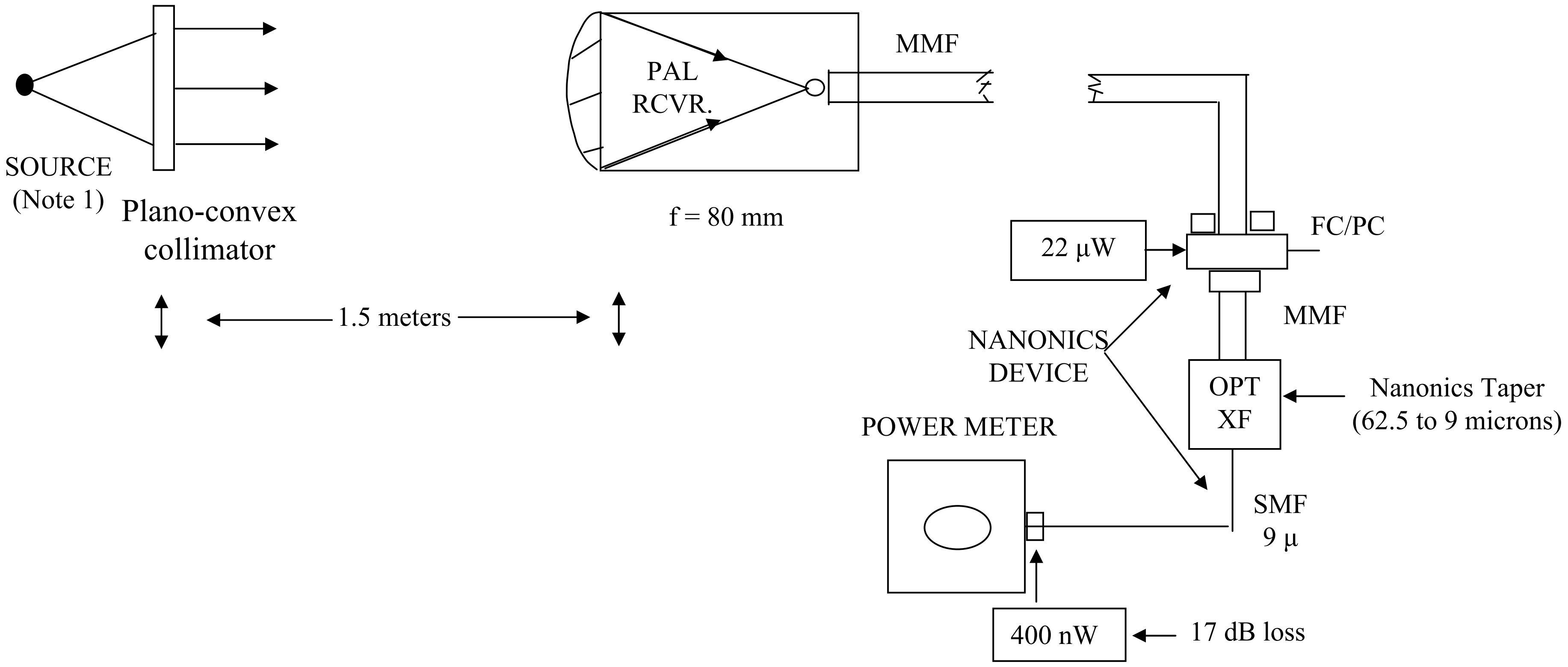


Optical Wireless WDM Experimental Arrangement

Optical Wireless WDM
Experimental Arrangement



Experimental test under FSO conditions of Nanonics OPT XF



Experimental test under FSO conditions of Nanonics OPT XF

Note: Same experiment repeated with taper from 200 to 70 microns and 75 micron photodiode 10 microns distant, 1 dB loss.

Future Research

- Large core broadband fiber with high N.A. (BW>200 MHz-km for d>150 microns)
- CWDM demux with large core common input fiber
- Large core EDFA
- Low capacitance, large area photodiodes (MSM?) (BW ≈10 GHz, d≥80 microns)
- Migration to 10 micron wavelength